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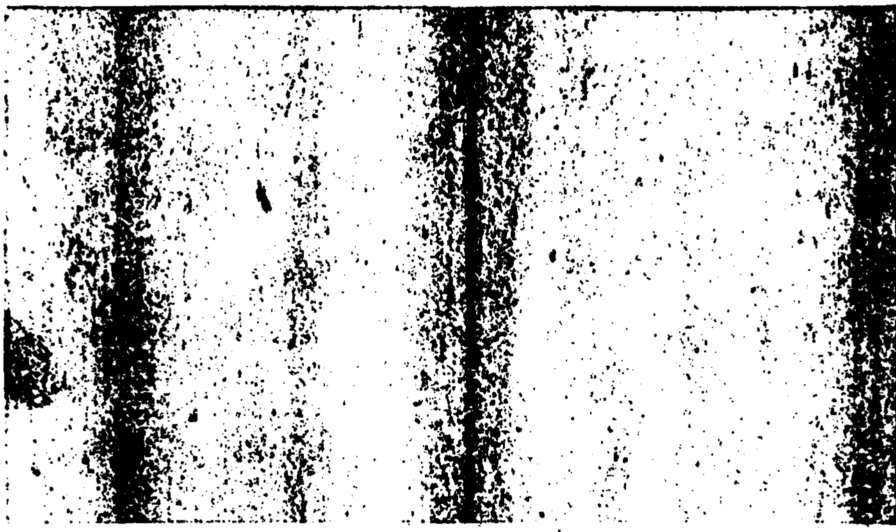

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MULTIBAND PYRAMID LINKING

Tsai-Hong Hong
Azriel Rosenfeld

Computer Vision Laboratory
Computer Science Center
University of Maryland
College Park, MD 20742

ABSTRACT

A method of image segmentation has been developed based on creating links between pixels in successive layers of a "pyramid" of reduced-resolution versions of the image. In the original implementation of this method, the links were based on comparing the values of a single feature, (average) gray level, for each pixel. In this note, the method is extended to links based on multiple features, such as color components or neighborhood properties.

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A method of image segmentation described in [1] is based on creating links between pixels in successive layers of a "pyramid" of reduced-resolution versions of the image. The method makes use of an "overlapped" pyramid in which each level is initially obtained by averaging 4-by-4 blocks of pixels on the level below, where these blocks overlap by 50% in the x and y directions; this implies that each pixel has four "fathers" on the level above it. To segment the image, we link each pixel (at each level of the pyramid) to that one of its four fathers whose gray level is most similar to its own. We now recompute the value of each pixel (on the levels above the image itself) by averaging only those pixels on the level below that are linked to it. Based on these new values, we change the links as necessary; recompute the values based on these new links; and so on, repeating the process until there is no further change (typically after a few iterations). The resulting final links define subtrees of the pyramid, having pixels as leaves and having roots at the uppermost level, which we usually take to be the 2-by-2 level. Each subtree thus defines a subset of the pixels (its leaves), so that we have segmented the image into (at most) four subsets.

The linking process need not be used on average gray level,; we can use any property that can be computed for the pixels of the image, and extend this property to the higher common gray level (four widely spaced levels were used). The red segmentation does not distinguish bushes from shadowed brick; the green segmentation breaks the bushes up into a grass-like and a shadow-like part; and the blue segmentation, besides not distinguishing bushes from shadow, breaks the sunlit brick into arbitrary subclasses. Figure 1c shows results when we use two colors at a time: green and blue in the left column, blue and red in the center column, and red and green in the right column. Here, the segmentations confuse parts of the bush class with the shadow class, but the blue/red segmentation gives a fairly good partitioning of the image into the four types of regions.

Figure 2a shows a local "busyness" measure computed for each pixel of the red, green, and blue images. [For the 3-by-3 neighborhood $\begin{matrix} a & b & c \\ d & e & f \\ g & h & i \end{matrix}$, this measure is defined by

$$\min(|a - b| + |b - c| + |d - e| + |e - f| + |g - h| + |h - i|,$$
$$|a - d| + |d - g| + |b - e| + |e - h| + |c - f| + |f - i|)$$

where the min is used to decrease the response to step edges, while retaining a high response in isotropic "busy" regions.] Figure 2b shows segmentation results based on busyness alone; the green result, in particular, gives fair discrimination between the bushes and the other regions, but the other regions themselves - as should be expected - are not distinguished. Figure 2c shows results when we use two features, gray level (in the given band) and busyness; none of these levels of the pyramid by averaging. If desired, we can begin the process by dividing the image into blocks, computing a property (e.g., a textural property) for each block, and building a pyramid starting from the resulting array of property values; linking in this pyramid yields a (blocky) segmentation of the image into (at most four) textured regions [2]. Other modifications of the basic pyramid linking process have been investigated, including the use of weighted rather than forced-choice links [3], as well as variations of the linking criterion that take positional information into account [4]. Methods of combining this linking scheme with image segmentation by recursive splitting into homogeneous regions have also been investigated [5].

The linking process need not be based on a single property; we can compute a property vector for each pixel (or block) and extend it to the higher levels of the pyramid by componentwise averaging. This note illustrates this generalization with some simple examples of pyramid linking based on pairs of properties.

Figure 1a shows the red, green, and blue bands of a color image of part of a house, showing sunlit and shadowed brick, bushes, and grass. Figure 1b shows the results of the pyramid linking process applied to each band separately; the pixels belonging to each of the four subtrees are displayed with a yields the four types of regions, but the results in the green band yield the brick (both sunlit and shadowed) as essentially a single region, while dividing the bushes into two classes. All results shown are for ten iterations.

Working with two features does not always yield significant improvement over working with single features. Table 1 shows classification results for two geological terrain types, Lower Pennsylvanian Shale and Pennsylvanian Sandstone and Shale, using three texture features, singly and pairwise. Each feature was the moment of inertia of a gray level co-occurrence matrix about its main diagonal (Haralick's "CON" feature), where the matrices were defined for the displacements shown in the second column of the table. In earlier texture classification studies using the same terrain types [6], these features individually had error rates of close to 25%, whereas pairwise they gave error rates of under 10%. In the present experiment, however, there is little or no improvement when pairs are used, probably because the error rates for single features are so low.

In conclusion, these examples illustrate how the basic pyramid linking method may sometimes yield a richer class of segmentations by using more than one property to characterize the pixels. Pyramid linking appears to deserve further investigation as a general approach to image segmentation.

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Feature No.	Displacement	Error rate(%)	Feature pair	Error rate(%)
1	(1,0)	4.3	2&3	3.3
2	(0,1)	6.4	3&1	5.2
3	(0,2)	14.2	1&2	6.2

Table 1. Classification results for geological terrain types

(a)

(b)

(c)

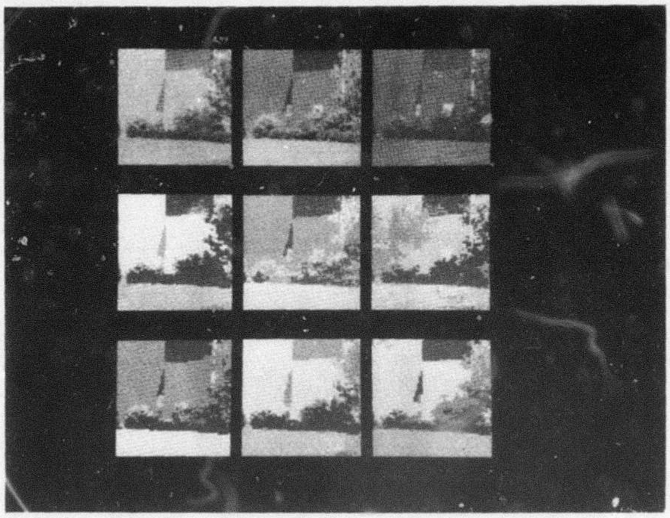

Figure 1. a) House image: red, green and blue components
b) Results of pyramid linking applied to each band separately
c) Results using pairs of bands: green/blue, blue/red, red/green

(a)

(b)

(c)

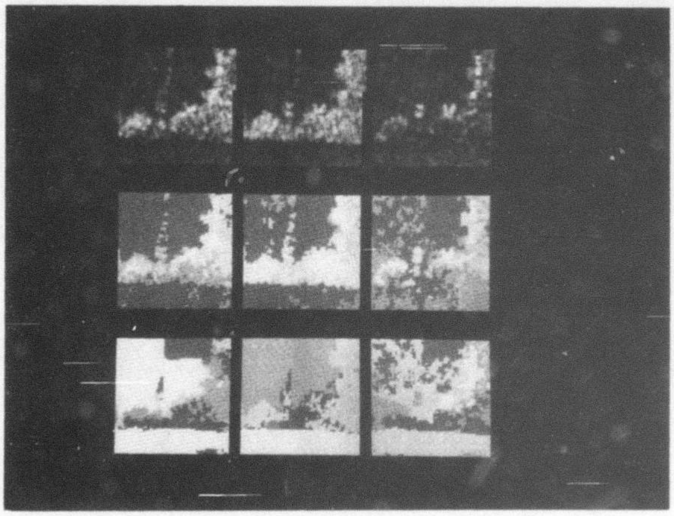

Figure 2. a) "Busyness" values in the three bands
b) Results of pyramid linking applied to these values
c) Results using (intensity, busyness) feature pair in each band

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